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MORTALITY OF MACKEREL CONFINED IN NETS

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ABSTRACT

In the summer of 1979 field experiments were carried out off Cornwall to investigate the effects on mackerel (*Scomber scombrus* L.) of the drying-up and slipping operations performed by purse-seiners. This was done by confining mackerel in floating keep-nets and subsequently releasing them into larger nets.

The results of this investigation are combined with those from a similar one performed at the same location in 1976, and the observed mortality is related to a stress index (S_I) derived from the density at which the fish were held in the dried-up net and the time they were held at that density.

INTRODUCTION

In August 1976, staff from the Fisheries Laboratory, Lowestoft conducted a series of experiments in Mevagissey Bay, Cornwall (50°15'N 04°47'W) designed to simulate the effects on mackerel (*Scomber scombrus*) of the 'drying-up' and 'slipping' operations performed by purse-seiners. This followed reports that large quantities of dead mackerel were being taken in bottom trawls in an area where slipping by purse-seiners was allegedly practised. The results of these experiments were described by Lockwood, Pawson and Mumford (1977) and by Pawson and Lockwood (1978). Further investigations were carried out at the same location during the period 11 August-8 September 1979. The results have been combined with those from 1976 in order to provide a more complete understanding of the effects of physical stress on mackerel.

MATERIALS AND METHODS

(i) Fishing

Two boats were used to obtain the fish, one operating out of Falmouth and the other from Mevagissey. The fish were caught on handlines fitted with barbless, feathered hooks (Bolster, 1974) and transported back to the experimental nets in circular fibre-glass deck tanks, 2 m in diameter with a water depth of 0.75 m. A constant flow of sea water through the tank at ambient temperature was maintained using the ship's deck hose. An 18 mm plywood cover, with a central 1 m^2 opening and downward projecting baffles, was bolted over the tank providing rigidity and helping to reduce turbulence. Only fish cleanly hooked through the lower lip with no apparent physical damage were placed in the tank. The fish retained for use were not handled or allowed to come into contact with any part of the boat, and were transferred to the experimental nets from the deck tank using dip nets constructed of fine mesh, knotless netting, in order to reduce any damage which might be caused by chafing. A further inspection of the fish was made during the transference to the nets, and any suspect fish were rejected.

(ii) The nets

All nets were made from white nylon netting of 210/18 twine with a stretched mesh size of 23 mm. The construction of the nets used in 1976 is described by Lockwood *et al.* (1977).

Two sizes of net were used in 1979; two each of 1 m^3 capacity and two of 3 m^3. The net for each of these was cut as two panels with the meshes hanging square. One panel formed a side and the bottom of the net, the second panel made the remaining three sides. The net was suspended from a frame made with 101 mm grade E (industrial 12.5 mm wall) Durapipe using nylon mending twine, and was weighted on the vertical corners with galvanized steel chain. The Durapipe frames were buoyant but, as a precaution, sausage floats were lashed to two sides, two per side, on the 3 m^3 nets. The mooring arrangement of the nets is shown in Figure 1.

(iii) Experimental and sampling techniques

Known numbers of selected fish in outwardly good condition from the deck tanks were placed in the 1 m^3 net and held for a known time, after which they were released into the 3 m^3 net where the density of fish was always less than 6 per m^3. Regular observations of their external appearance for signs of damage were made using a glass-bottomed bucket, and the dead fish were counted. At the end of each experiment surviving fish were removed from the net and inspected for damage. Removal of the fish from the 3 m^3 nets was achieved by hauling up one side of the net, thus slowly reducing the net volume to a point where dip nets could be effectively used. This appeared to cause little disturbance to the fish. In addition to these experiments, others were performed in which fish were held at known densities for varying times in a 1 m^3 net fitted with a plywood cover. Apart from regular observation these fish were left undisturbed in the net and the mortality recorded periodically.

RESULTS

A total of seven 'slipping' experiments were performed in 1979, and the data were combined with those from two similar experiments performed in 1976. The cumulative percentage mortality amongst the mackerel at each set of conditions was calculated and mortality curves were constructed. A visual inspection of these suggested that the observed death rate after slipping might be linear over the period of each experiment. Linear regressions were therefore calculated (Figure 2) and correlation coefficients varying between 0.82 and 0.99 were obtained. Table 1 summarises the slipping experimental conditions and the results obtained. An analysis of covariance of the regressions showed that all were significantly different at the 95% probability level, and no common regression could be fitted to the data or any combination thereof.

The density at which the fish were held in the 1 m^3 net, multiplied by the time they were held at that density (hours), gives a measure of the degree of stress each set of experimental conditions imposed upon the fish. This stress index (S_I; column 5, Table 1) was regressed with the expected mortality after 48 hours (M_{48}) obtained from the above linear regressions at each level of S_I used (Table 1, column 11). A logarithmic curve fits the data, generating the regression equation:

$$M_{48} = 25.22 \ln S_I - 79.56 \quad (r = 0.98).$$

An 'anovar' of the regression (goodness of fit test) gives an F value of 243.12 (1, 7 d.f.), significant at the 99.9%+ level of probability.

In 1979 five experiments were performed in which the fish were continually confined at known densities in the 1 m^3 net. Two sets of data were discarded, one due to heavy predation by gulls (a plywood cover to the net was subsequently used) and another where the results were deemed to have been influenced by adverse weather conditions affecting the net shape and volume. The results from the remaining three experiments were combined with those of four similar experiments from the 1976 investigations and regression lines fitted as previously (Table 2 and Figure 3). An analysis of covariance of these regressions showed that experiments 2, 4, 6, 7 and 8 (holding densities in the range 5-44 fish per m^3) could be represented by a common regression described by the equation

$$y = 0.448x - 0.184,$$

where x is the time the fish were confined in the net (hours) and y the cumulative percentage mortality. This and the regressions for experiments 5 and 9 (100 and 500 fish per m^3 respectively) were all significantly different at the 99.9% level of probability.

Using these data, the regression of M_{48} against S_I was corrected for a holding density after slipping of 5 fish per m^3, and using coordinates obtained from this regression a series of curves was constructed showing the expected mortality 48 hours after slipping of mackerel held at different densities in the net (Figure 4).

RESULTS OF THE QUALITATIVE DATA OBTAINED FROM SLIPPING EXPERIMENTS

The external condition of both dead fish removed from the net during the course of the experiments and those fish surviving at the end of the experiments was recorded as one of three categories:

1 no apparent damage (NAD);

2 fish suffering loss of skin;

3 fish with healing patches (HP), characteristically cloudy areas of thickened mucus.

The proportions of dead and surviving fish in each category are given in Table 3. Ninety per cent of the surviving fish showed evidence of skin damage, assumed to be caused by abrasion as a result of vigorous or constant contact with the netting, and probably mutual abrasion between fish prior to slipping. Damage was most often observed along the posterior flanks of the fish, the area of greatest movement during the lateral flexing of the body whilst swimming. A lower proportion of the dead fish (42%) was damaged in this way. Observations suggest that skin loss as a result of abrasion will occur within 3 days of the fish suffering damage. That 58% of the fish dying showed no apparent damage suggests that death was due to causes other than osmotic imbalance as a result of skin loss. During the course of the experiments the physiological causes of death were investigated by studying the blood biochemistry and respiration of mackerel. The results of these investigations will be reported elsewhere (Boutilier *et al.*, in preparation).

When mackerel skin was abraded, mucus and some scales were lost. The outer layer of epidermis, which includes the chromatophores, began to blister and after a minimum of 24 hours in severe cases, but more usually 2 to 3 days, these blisters burst and the skin began to peel away. Immediately following skin loss, the underlying muscle tissue was still covered with a silvery layer of guanine, but this was rapidly lost exposing the muscle tissue. The skin loss was progressive. But if the abrasion was very slight, discoloured patches could be observed over the damaged sites but blisters did not develop. If these areas were lightly abraded the skin came away easily, whereas surrounding undamaged skin remained intact. Because these patches were never seen in conjunction with skin blisters and were most commonly observed on fish which had been confined in the holding nets for several days, it was considered as reasonable to assume that they were part of the fish's natural healing process. But these fish must be extremely susceptible to further damage, and, bearing in mind the possibility of subsequent recapture during the main fishing season off Cornwall (November to February) should such fish be slipped from a net, their survival rate must be adjudged to be very low. Mackerel exhibiting the aforementioned symptoms have been taken by fisheries research vessels off the south-west coast of the British Isles.

DISCUSSION

The results of the 1979 investigation support the preliminary findings arising from the 1976 experiments: namely, that mackerel are an extremely delicate species compared with other commercially important demersal species, and are likely to suffer a high mortality when held at densities adjudged to be comparable with those commonly observed in dried-up purse-seine nets during commercial fishing operations.

The combined results from the 1976 and 1979 investigations provide mortality data for mackerel confined for different periods of time at densities in the range 5-1500 fish per m^3. Based upon observations of commercial purse-seiners at work, it is estimated that a minimum density of 500 fish per m^3 is required in the dried-up purse before effective pumping operations can begin, at which point a small sample would be taken on board to ascertain the quality of the catch. On the evidence of this sample the remaining catch would be either slipped or pumped inboard. The results show that although mackerel held at this estimated minimum density or greater appear undamaged, and swim away freely when slipped from the net, they will, however, suffer a high mortality within a relatively short time. Thus, using Figure 4, it can be predicted that 60% of the slipped catch, previously held for 30 minutes at a density of 500 fish per m^3, would be expected to die within 48 hours of release. This will of course be a minimum estimate as fish will continue to die after the 48 hour period at liberty has elapsed.

This has certain implications for the mackerel stock management strategy. Any recommendations appertaining to a minimum landing size for mackerel will encourage an increased incidence of slipping by purse-seine skippers where the catch is deemed to contain a large proportion of undersized fish. In addition, the limitation of total catches might also be expected to lead to an increase in discarding as skippers exercise a degree of selection on catches landed in response to quota restrictions and market forces. In either case, there would result an underestimation of mortality due to fishing, and this could lead to an overestimation of the mackerel stock size.

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Table 1 Summary of the Mevagissey slipping experiment data

Expt	Date	Fish density per m^3	Stress time (hours)	Stress index (S_I)	Duration of expt (hours)	Holding density after slipping (F/M^{-3})	Cumulative mortality (%)	Regression equation	r	M_{48} (%)
1	22 Aug 1979	127	0.5	63.5	71.8	4.7	44.9	y = 0.58x + 2.71	0.99	30.6
2	"	141	0.5	70.5	71.8	5.2	34.8	y = 0.46x + 1.87	0.99	24.0
3	27 Aug 1979	148	0.25	37.0	125.4	5.5	9.5	y = 0.10x + 0.93	0.96	5.7
4	"	146	0.25	36.5	107.9	5.4	11.0	y = 0.09x − 0.40	0.99	3.9
5	1 Sep 1979	82	0.25	20.5	46.9	3.0	7.7	y = 0.17x − 0.43	0.99	7.7
6	4 Sep 1979	142	0.17	23.7	53.0	5.3	4.2	y = 0.07x − 0.54	0.85	2.8
7	2 Sep 1979	100	0.37	36.7	43.0	3.7	5.0	y = 0.12x + 1.24	0.82	7.0
8	25 Aug 1976	1000	0.50	500.0	45.0	1.1	74.0	y = 1.66x − 2.86	0.99	76.8
9	27 Aug 1976	1500	0.75	1125.0	21.0	1.6	99.3	y = 4.83x − 5.79	0.98	100.0

y = cumulative percentage mortality
x = time (hours) elapsed after slipping

Table 2 Summary of mackerel crowding experimental data

Expt	Date	Fish density per m^3	Duration (hours)	Cumulative mortality (%)	Regression equation	r	M_{48} (%)
2	21 Aug 1979	40	75.5	35.0	y = 0.5 x - 3.28	0.96	20.5
4	28 Aug 1979	32	149.5	62.5	y = 0.45x + 1.06	0.96	22.6
5	4 Sep 1979	100	54.75	56.0	y = 1.12x - 2.84	0.99	50.7
6	16 Aug 1976	5	68.0	23.0	y = 0.37x + 1.18	0.98	18.7
7	17 Aug 1976	44	23.5	9.9	y = 0.37x + 1.54	0.95	19.4
8	"	44	33.5	14.0	y = 0.40x + 1.90	0.94	21.0
9	25 Aug 1976	500	20.0	99.4	y = 4.81x + 14.59	0.89	100.0

x = time (hours) confined in the net
y = cumulative percentage mortality

Table 3 Qualitative assessment of the damage suffered by mackerel during the simulated 'slipping' experiments

	NAD (%)	HP (%)	Skin loss (%)
Dead	58	6	36
Surviving	10	65	25

NAD - fish suffering no apparent damage
HP - fish showing healing patches

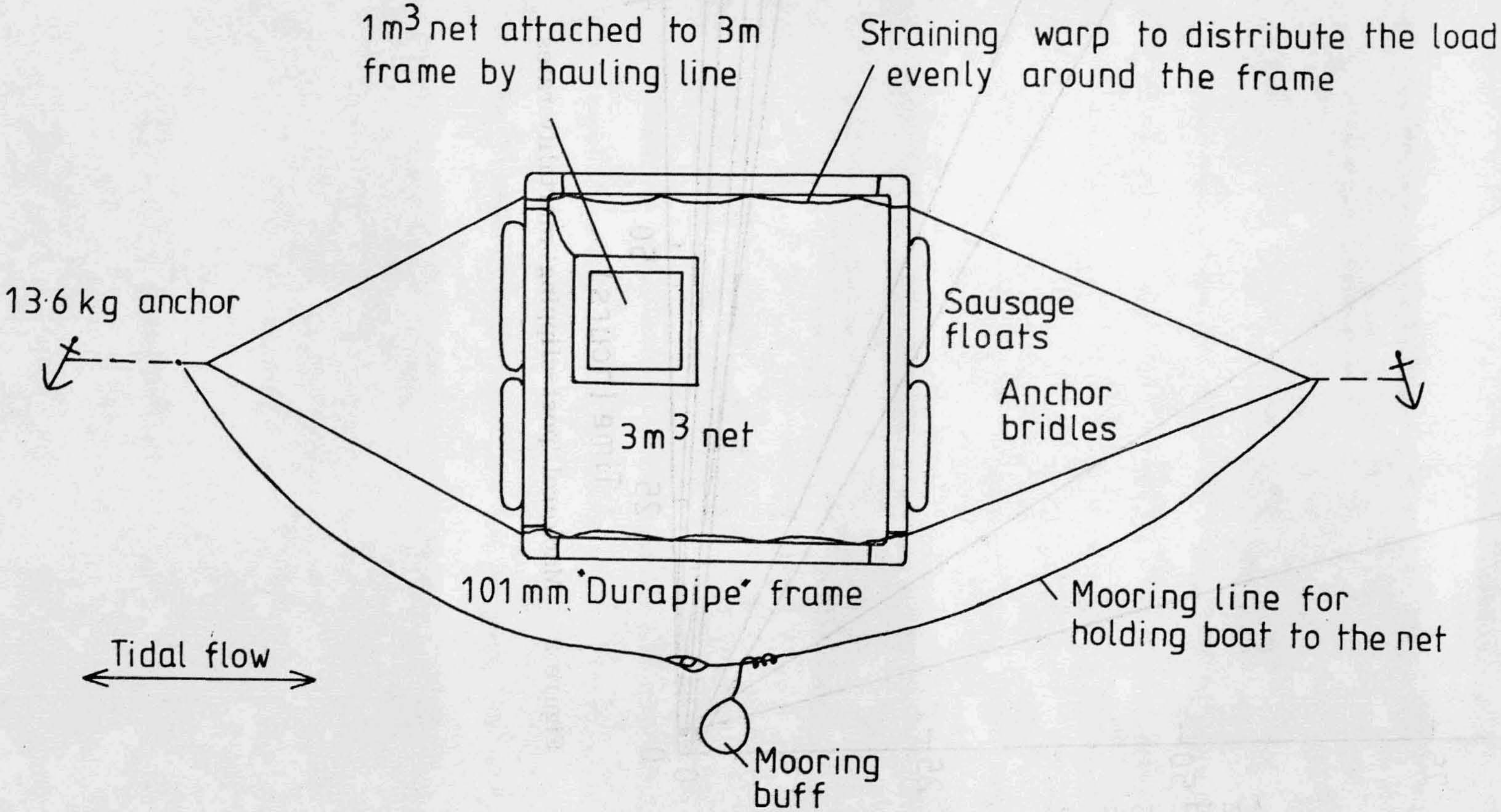

Figure 1 Mooring arrangement of the nets.

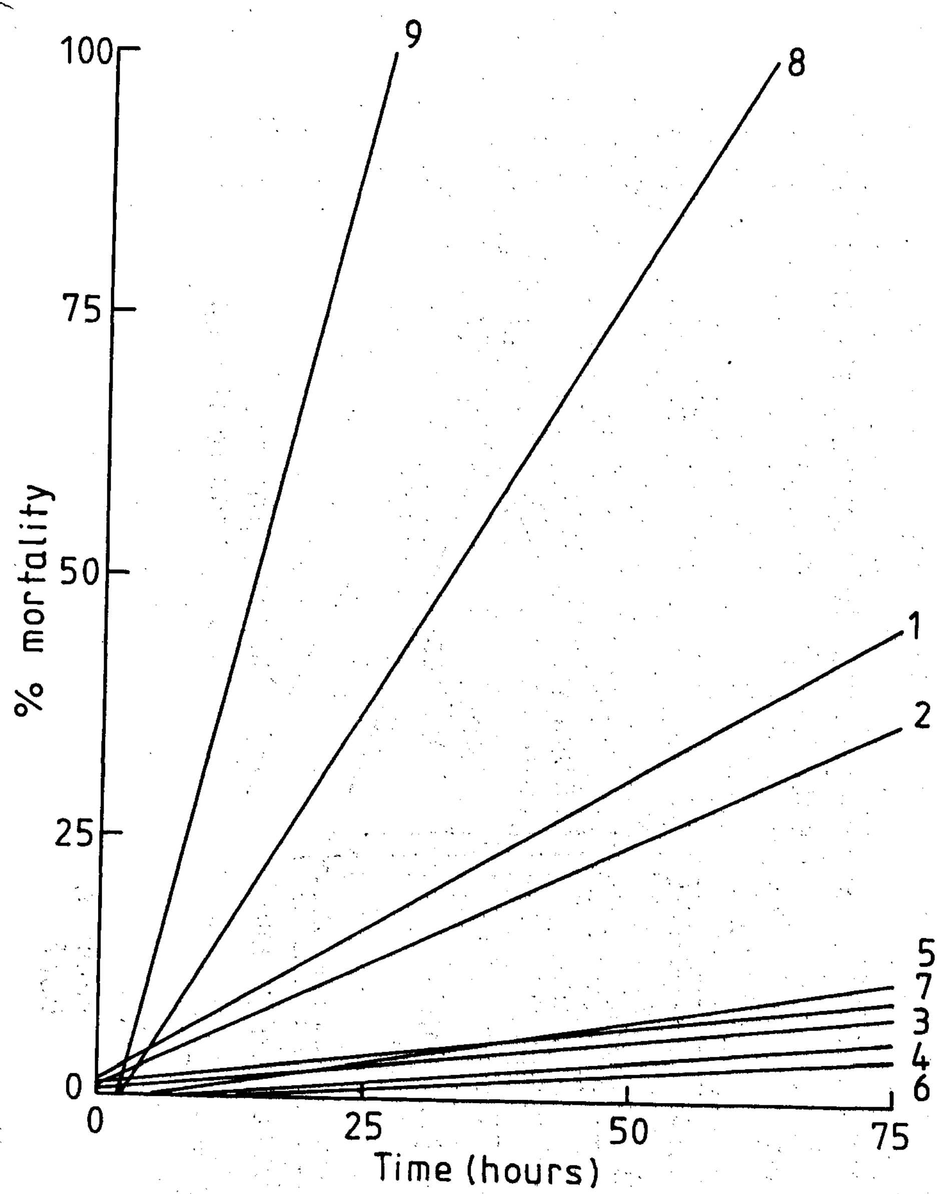

Figure 2 Mackerel 'post-slipping' mortality rates.

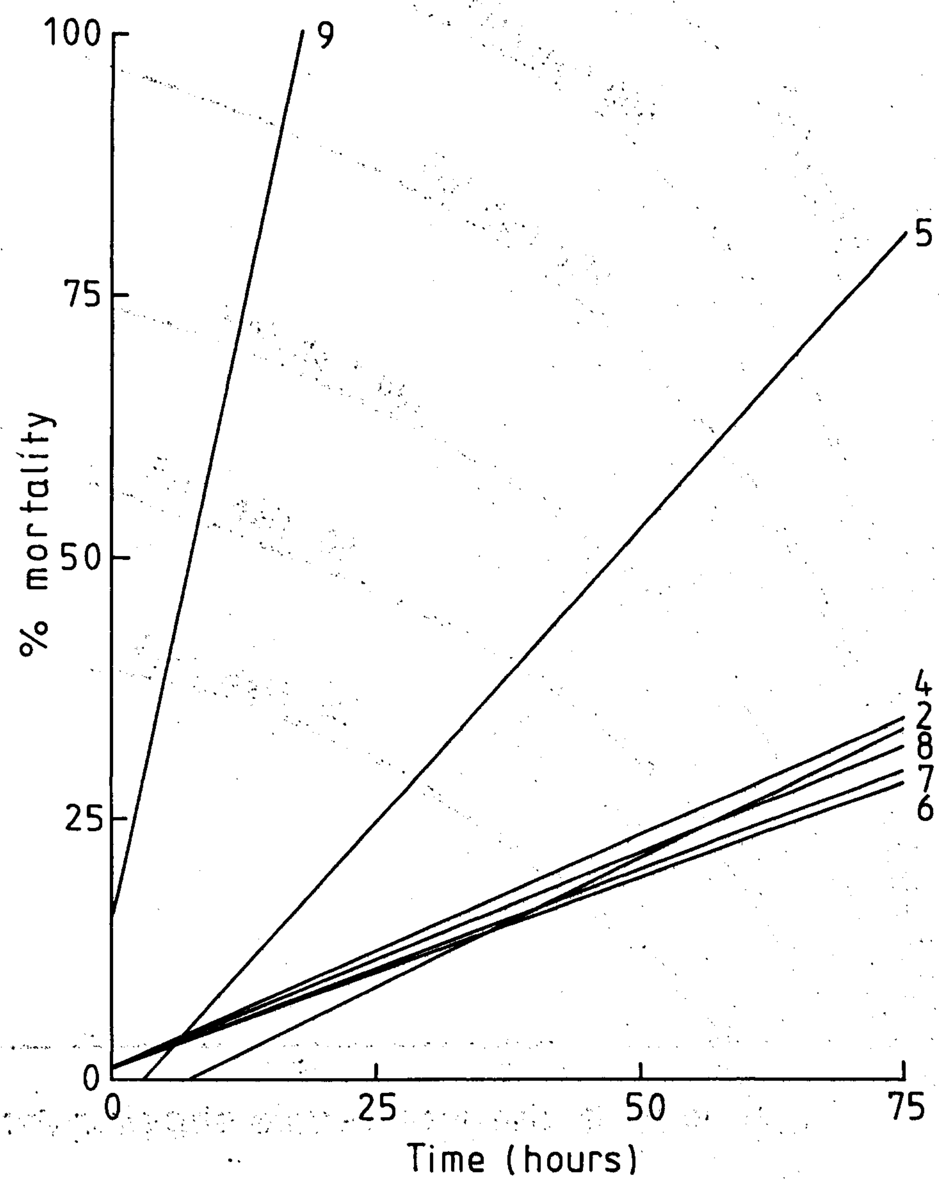

Figure 3 Mackerel crowding experiment: mortality rates.

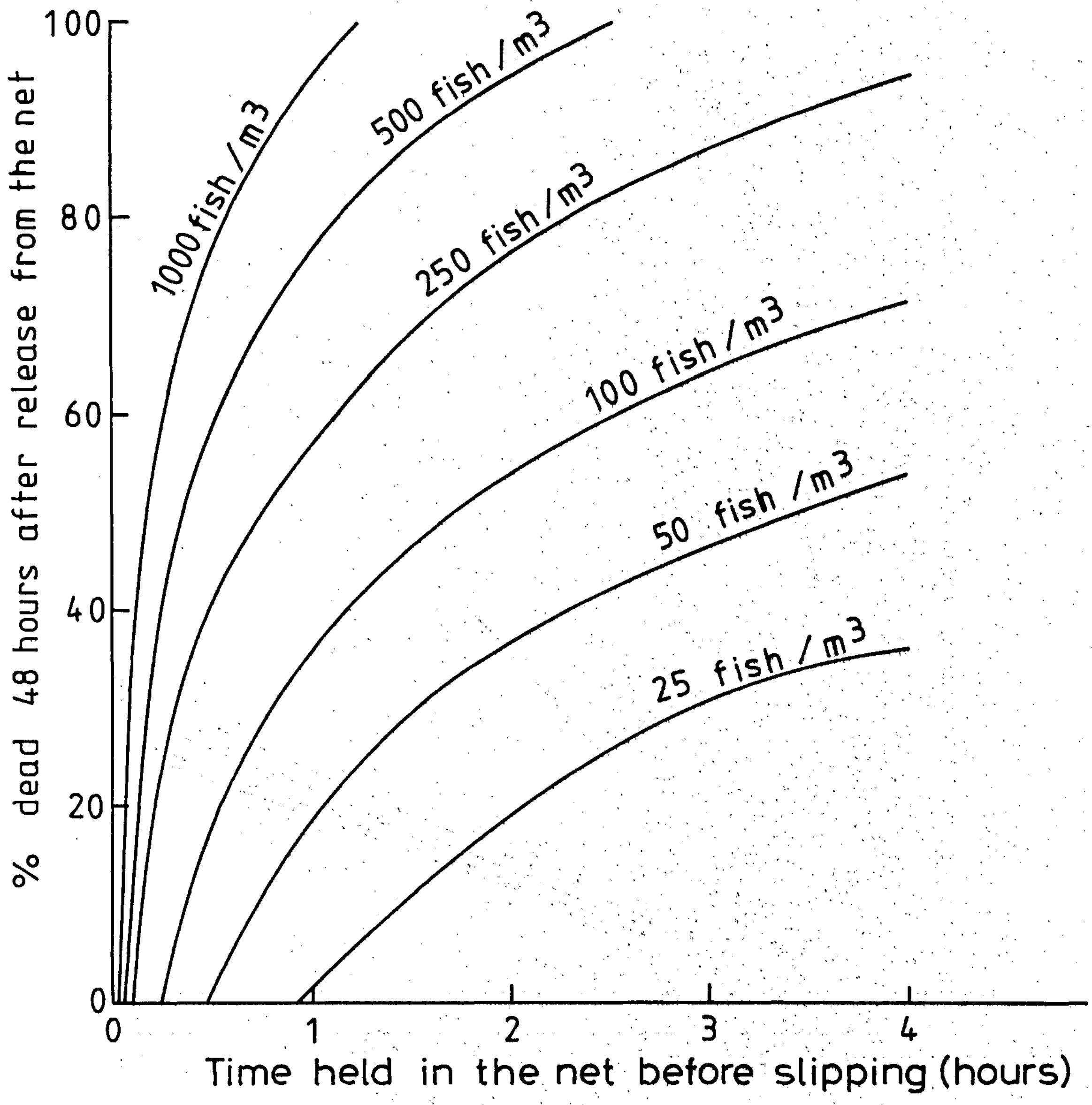

Figure 4 'Post-slipping' mortality rates of mackerel held at different densities.